

## REMARKS

The Applicants thank the Examiner for the careful examination of this application and respectfully request entry of the amendments indicated hereinabove. The Applicants also thank the Examiner for the indication of allowance of Claims 51-59. Claims 1, 5-13, 30-39, and 51-68 are pending and rejected.

The Applicants respectfully traverse the rejection of Claims 1 and 5-13 under 35 U.S.C. §112, first paragraph. The Applicants submit that wording “a plasma annealing process” in Claim 1 is described in the Specification. Namely, the Specification clearly states on page 11 lines 13-15 that the anneal may be performed with “the same tool” as that used for step 106 (which is a plasma tool – see page 9 lines 13-17). The Applicants note that on page 11 line 28 to page 12 line 15 the Specification describes the benefit of reducing copper-oxide to metallic copper (thus enhancing the conductivity of the exposed metal just prior to barrier and Cu deposition). If the process were a non-plasma anneal then the reduction aspect would not be possible (since passing H<sub>2</sub> gas over Cu-oxide is not sufficient to produce the reaction of Cu-oxide to convert to metallic copper). The Applicants also note that on page 11 line 23 the term “nitrogen-containing plasma” is a clear indication that step 110 is a plasma step and is also a ‘written description’ in support of the term “plasma” in Claim 5.

The Applicants respectfully traverse the rejection of Claims 30-39 under 35 U.S.C. §112, first paragraph. The Applicants submit that wording “the first material

is reactive with oxygen plasma” in Claim 30 is described in the Specification. Namely, the Specification clearly states on page 2 line 29 to page 3 line 14 that the prior art oxygen-based plasma processes caused unwanted degradation of dielectric materials (see page 3 line 2). In addition on page 6 lines 13-19, the Specification describes the advantageously claimed process “in which a low-dielectric constant layer or any materials negatively affected with the use of oxygen plasma is included.”

Claim 1 positively recites the step of removing the polymeric residue by subjecting the semiconductor wafer to a wet etch chemistry. In addition, Claim 1 positively recites subjecting the semiconductor wafer to a plasma annealing step. These advantageously claimed features are not taught or suggested by the patents granted to Kropewnicki et al. or Torek et al., either alone or in combination.

The Applicants respectfully traverse the statement in the Office Action (page 4) that Kropewnicki et al. teaches the use of wet etch chemistry for removing the polymeric residue. The Applicants submit that if Kropewnicki et al. taught the step of subjecting the wafer to a wet etch chemistry then the Examiner should be able to point to such a step in the teachings of the invention contained in the Description section of the Specification – instead of referencing just the Background section. Moreover, Kropewnicki et al. teaches away from the use of wet cleans (col. 1, lines 48-58) while teaching the desirability of the use of a dry clean process (col. 1, line 66 through col. 2, line 44). Specifically, Kropewnicki et al. considers the wet clean process undesirable; stating (column 1 lines 44-57) that the wet clean process requires a solvent that is costly and hazardous to the environment, contributes to

lower yield because the substrate is contaminated in the transferring operation, and oxidizes contact/junction points. Furthermore, the Applicants submit that the EKC 265 solvent listed in column 1 line 46 is not capable of removing the polymeric residue on the first material of Claim 30 (the Applicants tested EKC and saw no residue removal – according to scanning electron micrographs - for the materials described in the Specification and claimed). Specifically, the MSDS for EKC 265 reveals that it contains 2-(2-Aminoethoxy) ethanol plus hydroxylamine plus catechol. Therefore, EKC 265 is very inferior to the advantageously claimed mixture at removing the type of polymer found on wafers after dielectric etch and resist removal.

Furthermore, the Kropewnicki et al. patent describes the use of a mostly O<sub>2</sub> plasma for resist and residue removal (column 10 lines 36-41; see also column 6 lines 56-58 and 67, column 7 lines 1, 29-30, 46, and 51, column 8 lines 63-64, column 9 lines 7, 54-55, 57, and 64-67, column 10 lines 23-25, 45-46, and 62-64, column 11 lines 3-4 and 7-9). Therefore, Kropewnicki et al. teaches away from the advantageously claimed invention that explicitly excludes the use of any oxygen (note the absence of oxygen in the Applicants' claims and see also the Applicants Specification on page 10 line 7). As described by the Applicants in the Specification (page 2 line 29 to page 3 line 14), the cleaning chemistries taught by Kropewnicki et al. would be harmful when used in applications with exposed low-k dielectrics, due to the reaction of the O<sub>2</sub> plasma with the low-k material.

In addition, the Applicants respectfully traverse the statement in the Office Action (page 4) that Kropewnicki et al. teaches the step of subjecting the

semiconductor wafer to a plasma which includes hydrogen. The Applicants submit that Kropewnicki et al. teaches the use of an additive gas that contains H but Kropewnicki et al. does not list H<sub>2</sub> in his gas mixture (column 6 lines 58-59, column 7 lines 2, 7-34, 47, and 52, column 9 lines 2-4, column 10 lines 57-60).

Kropewnicki et al. describes the use of an etching chamber to remove the photoresist and post etch and ash polymeric residues (i.e. col. 2, lines 36-44). The Applicants downstream plasma tool (page 9 lines 13 – 17) operates in a completely different regime that includes higher process pressure, much higher gas flows, much higher temperatures, and no biasing of the wafer. Conversely, Kropewnicki et al requires biasing of the wafer (col. 2, line 22). The Applicants submit that the Kropewnicki et al. process produces substantial damage to low-k dielectric material.

The Applicants respectfully traverse the statement in the Office Action (page 5) that “it would have been obvious to a person of ordinary skill in the art to perform an annealing step.” The Applicants question why there is no art cited in the Office Action which supports the Examiner’s claim. The Applicants submit that it is because it is not obvious to perform an annealing step after H-plasma resist removal and wet clean, as advantageously claimed.

The Applicants respectfully traverse the assertion in the Office Action (page 6) that Torek et al. teaches the advantageously claimed wet etch chemistry. The Applicants submit that a person of ordinary skill in the art would not use the Torek et al. teachings in the advantageously claimed method because Torek et al. is silent as to the nature of the plasma clean before the wet clean (column 3 lines 28-30,

column 4 lines 25-32) and that information is critical to the issue of wet clean effectiveness. For example, Torek et al. teaches away from Claim 9 when Torek et al. teaches that citric acid is optional (column 6 lines 54-55). For another example, Torek et al. teaches away from Claim 7 when Torek et al. teaches that the clean should have three or more components (column 3 lines 46-48, column 5 lines 43-45). Moreover, the Applicants respectfully traverse the statement in the Office Action that it would be obvious to combine the teachings of Torek et al. with Kropewnicki et al. because a person of ordinary skill in the art would not combine a wet clean of HF plus organic acid (Torek et al.) with EKC (Kropewnicki et al.).

Therefore, the Applicants respectfully traverse the Examiner's rejection of Claim 1 and respectfully assert that Claim 1 is patentable over the patents granted to Kropewnicki et al. and Torek et al., either alone or in combination. Furthermore, Claims 5-13 are allowable for depending on allowable independent Claim 1 and, in combination, including limitations not taught or described in the references of record.

Claim 30 positively recites the step of removing the polymeric residue by subjecting the semiconductor wafer to a wet etch chemistry. These advantageously claimed features are not taught or suggested by the patents granted to Kropewnicki et al., Torek et al., or Hillyer et al. either alone or in combination.

The Applicants respectfully traverse the statement in the Office Action that Kropewnicki et al. teaches the use of wet etch chemistry for removing the polymeric

residue. Kropewnicki et al. teaches away from the use of wet cleans (col. 1, lines 48-58) while teaching the use of a dry clean process (col. 1, line 66 through col. 2, line 44). More specifically, Kropewnicki et al. considers the wet clean process undesirable; stating (column 1 lines 44-57) that the wet clean process requires a solvent that is costly and hazardous to the environment, contributes to lower yield because the substrate is contaminated in the transferring operation, and oxidizes contact/junction points. Furthermore, the Applicants submit that the EKC 265 solvent listed in column 1 line 46 is not capable of removing the polymeric residue on the first material of Claim 30. Specifically, the MSDS for EKC 265 reveals that it contains 2-(2-Aminoethoxy) ethanol plus hydroxylamine plus catechol. Therefore, EKC 265 is very inferior to the advantageously claimed mixture at removing the type of polymer found on wafers after dielectric etch and resist removal.

The Applicants respectfully traverse the statement in the Office Action that “clearly in col. 2, lines 1-10, the polymeric residue can be removed by using either a wet or dry chemistry.” The Applicants submit that  $\text{NH}_3$  is used in Kropewnicki et al. as a gas component of a plasma process. Specifically, the Kropewnicki et al. patent describes the use of  $\text{NH}_3$  gas in a plasma as an additive to a mostly  $\text{O}_2$  plasma for resist and residue removal. There is no mention of using a wet process in that portion of the Kropewnicki et al. patent.

Kropewnicki et al. describes the use of an etching chamber to remove the photoresist and post etch and ash polymeric residues (i.e. col. 2, lines 36-44). The Applicants downstream plasma tool (page 9 lines 13 – 17) operates in a completely different regime that includes higher process pressure, much higher gas flows,

much higher temperatures, and no biasing of the wafer. Conversely, Kropewnicki et al requires biasing of the wafer (col. 2, line 22). The Applicants submit that the Kropewnicki et al. process produces substantial damage to low-k dielectric material.

For the reasons presented above, the Applicants respectfully traverse the Examiner's rejection of Claim 30 and respectfully assert that Claim 30 is patentable over Kropewnicki et al.

Regarding Claims 31-39, the Applicants respectfully traverse the assertion in the Office Action (page 6) that Torek et al. teaches the advantageously claimed wet etch chemistry. The Applicants submit that a person of ordinary skill in the art would not use the Torek et al. teachings in the advantageously claimed method because Torek et al. is silent as to the nature of the plasma clean before the wet clean (column 3 lines 28-30, column 4 lines 25-32) and that information is critical to the issue of wet clean effectiveness. For example, Torek et al. teaches away from Claim 32 when Torek et al. teaches that citric acid is optional (column 6 lines 54-55). For another example, Torek et al. teaches away from Claim 31 when Torek et al. teaches that the clean should have three or more components (column 3 lines 46-48, column 5 lines 43-45). Moreover, the Applicants respectfully traverse the statement in the Office Action that it would be obvious to combine the teachings of Torek et al. with Kropewnicki et al. because a person of ordinary skill in the art would not combine a wet clean of HF plus organic acid (Torek et al.) with EKC (Kropewnicki et al.).

Regarding Claims 36-39, Hillyer et al. discloses the use of oxygen in the plasma (column 4 lines 14, and 38-43). This is in contrast to the Applicants teaching that the use of oxygen is excluded (page 10 line 7).

In addition, Hillyer et al. teaches the use of a wet clean after the  $\text{NH}_3$  plasma treatment (column 4 lines 54-62). In summary, Hillyer et al. teaches a cleaning procedure comprised of a plasma resist removal, then plasma residue removal, and then wet clean (to remove the now soluble residues). In contrast, the Applicants teach H-plasma resist removal and then a wet clean. The two cleaning procedures are quite different.

Lastly, the Applicants traverse the statement in the Office Action (page 6) that it would be logical to combine the mixture of Hillyer et al. with the mixture of Kropewnicki et al. because Hillyer et al. teaches the use of 25-100%  $\text{NH}_3$  (column 4 lines 39-42) but Kropewnicki et al. teaches the use of small amounts of  $\text{NH}_3$  (column 7 line 22-24). In fact, Kropewnicki et al. states that "it has been further discovered that excessive amounts of  $\text{NH}_3$  addition can adversely affect the cleaning rate" (column 7 lines 14-16).

Therefore, the Applicants respectfully traverse the Examiner's rejection of Claim 30 and respectfully assert that Claim 30 is patentable over Kropewnicki et al., Torek et al., and Hillyer et al. either alone or in combination. Furthermore, Claims 31 - 39 are allowable for depending on allowable independent Claim 30 and, in combination, including limitations not taught or described in the references of record.



Claim 60 positively recites the step of removing the polymeric residue by subjecting the semiconductor wafer to a wet etch chemistry. These advantageously claimed features are not taught or suggested by the patent granted to Kropewnicki et al.

The Applicants respectfully traverse the statement in the Office Action (page 4) that Kropewnicki et al. teaches the use of wet etch chemistry for removing the polymeric residue. The Applicants submit that if Kropewnicki et al. taught the step of subjecting the wafer to a wet etch chemistry then the Examiner should be able to point to such a step in the teachings of the invention contained in the Description section of the Specification – instead of referencing just the Background section. Moreover, Kropewnicki et al. teaches away from the use of wet cleans (col. 1, lines 48-58) while teaching the desirability of the use of a dry clean process (col. 1, line 66 through col. 2, line 44). Specifically, Kropewnicki et al. considers the wet clean process undesirable; stating (column 1 lines 44-57) that the wet clean process requires a solvent that is costly and hazardous to the environment, contributes to lower yield because the substrate is contaminated in the transferring operation, and oxidizes contact/junction points. Furthermore, the Applicants submit that the EKC 265 solvent listed in column 1 line 46 is not capable of removing the polymeric residue on the first material of Claim 30. Specifically, the MSDS for EKC 265 reveals that it contains 2-(2-Aminoethoxy) ethanol plus hydroxylamine plus catechol. Therefore, EKC 265 is very inferior to the advantageously claimed mixture at removing the type of polymer found on wafers after dielectric etch and resist removal.

Furthermore, the Kropewnicki et al. patent describes the use of a mostly O<sub>2</sub> plasma for resist and residue removal (column 10 lines 36-41; see also column 6 lines 56-58 and 67, column 7 lines 1, 29-30, 46, and 51, column 8 lines 63-64, column 9 lines 7, 54-55, 57, and 64-67, column 10 lines 23-25, 45-46, and 62-64, column 11 lines 3-4 and 7-9). Therefore, Kropewnicki et al. teaches away from the advantageously claimed invention that explicitly excludes the use of any oxygen (see the Applicants Specification on page 10 line 7). As described by the Applicants in the Specification (page 2 line 29 to page 3 line 14), the cleaning chemistries taught by Kropewnicki et al. would be harmful when used in applications with exposed low-k dielectrics, due to the reaction of the O<sub>2</sub> plasma with the low-k material.

In addition, the Applicants respectfully traverse the statement in the Office Action (page 4) that Kropewnicki et al. teaches the step of subjecting the semiconductor wafer to a plasma which includes hydrogen. The Applicants submit that Kropewnicki et al. teaches the use of an additive gas that contains H but Kropewnicki et al. does not list H<sub>2</sub> as a requirement for his gas mixture (column 6 lines 58-59, column 7 lines 2, 7-34, 47, and 52, column 9 lines 2-4, column 10 lines 57-60).

Kropewnicki et al. describes the use of an etching chamber to remove the photoresist and post etch and ash polymeric residues (i.e. col. 2, lines 36-44). The Applicants downstream plasma tool (page 9 lines 13 – 17) operates in a completely different regime that includes higher process pressure, much higher gas flows,

much higher temperatures, and no biasing of the wafer. Conversely, Kropewnicki et al requires biasing of the wafer (col. 2, line 22). The Applicants submit that the Kropewnicki et al. process produces substantial damage to low-k dielectric material.

For the reasons presented above, the Applicants respectfully traverse the Examiner's rejection of Claim 60 and respectfully assert that Claim 60 is patentable over Kropewnicki et al.

Claim 61 positively recites the step of subjecting the semiconductor wafer to a plasma which incorporates a gas which includes a diluent and at least 50% hydrogen so as to remove the photoresist layer. These advantageously claimed features are not taught or suggested by the patents granted to Kropewnicki et al. or Hillyer et al., either alone or in combination.

The Applicants traverse the statement in the Office Action (page 7) that Kropewnicki et al. teaches the step of subjecting the wafer to a plasma which includes a diluent and hydrogen at column 6 lines 10-65. The Applicants submit that Kropewnicki et al. does not suggest H as a H-source and H is not itself sought as an active compound in the gas mixture (column 6 lines 58-59). In addition, Kropewnicki et al. teaches away from the advantageously claimed invention because Kropewnicki et al. teaches the use of additives where H quantities are far less than 50% by volume (column 7 lines 20-25).

Furthermore, the Kropewnicki et al. patent describes the use of a mostly O<sub>2</sub> plasma for resist and residue removal (column 10 lines 36-41; see also column 6

lines 56-58 and 67, column 7 lines 1, 29-30, 46, and 51, column 8 lines 63-64, column 9 lines 7, 54-55, 57, and 64-67, column 10 lines 23-25, 45-46, and 62-64, column 11 lines 3-4 and 7-9). Therefore, Kropewnicki et al. teaches away from the advantageously claimed invention that explicitly excludes the use of any oxygen (see the Applicants Specification on page 10 line 7). As described by the Applicants in the Specification (page 2 line 29 to page 3 line 14), the cleaning chemistries taught by Kropewnicki et al. would be harmful when used in applications with exposed low-k dielectrics, due to the reaction of the O<sub>2</sub> plasma with the low-k material.

Hillyer et al. discloses the use of oxygen in the plasma (column 4 lines 14, and 38-43). This is in contrast to the Applicants claims (Claims 61-68) and their teaching that the use of oxygen is excluded (page 10 line 7).

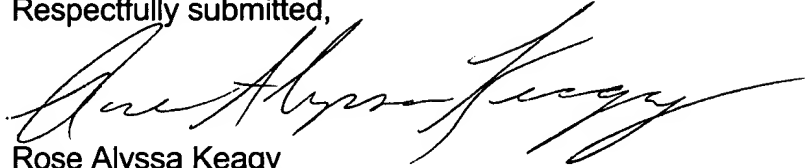
In addition, Hillyer et al. teaches the use of a wet clean after the NH<sub>3</sub> plasma treatment (column 4 lines 54-62). Namely, Hillyer et al. teaches a cleaning procedure comprised of a plasma resist removal, then plasma residue removal, and then wet clean (to remove the now soluble residues). In contrast, the Applicants teach H-plasma resist removal, a wet clean, and then a H-plasma anneal. The two cleaning procedures are quite different and result in different surface conditions. In fact, the Applicants submit that it is undesirable to end the process sequence with a wet clean (Hillyer et al.) because of the chance that volatile components may exist in pockets inside of the porous low-k material – leading to undesirable void formation during the metal deposition step.

Lastly, the Applicants traverse the statement in the Office Action (page 8) that it would be logical to combine the mixture of Hillyer et al. with the mixture of Kropewnicki et al. because Hillyer et al. teaches the use of 25-100%  $\text{NH}_3$  (column 4 lines 39-42) but Kropewnicki et al. teaches the use of small amounts of  $\text{NH}_3$  (column 7 line 22-24). In fact, Kropewnicki et al. states that "it has been further discovered that excessive amounts of  $\text{NH}_3$  addition can adversely affect the cleaning rate" (column 7 lines 14-16).

Therefore, the Applicants respectfully traverse the Examiner's rejection of Claim 61 and respectfully assert that Claim 61 is patentable over the patents granted to Kropewnicki et al. and Hillyer et al., either alone or in combination. Furthermore, Claims 62-68 are allowable for depending on allowable independent Claim 61 and, in combination, including limitations not taught or described in the references of record.

For the reasons stated above, this application is believed to be in condition for allowance. Reexamination and reconsideration is requested.

Respectfully submitted,

A handwritten signature in cursive script, appearing to read "Rose Alyssa Keagy".

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